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13. ABSTRACT *(Maximum 200 Words)*

The goals of this research project are to create the tools needed to analyze and understand loaded and switched antennas and to design the experimental apparatus needed to verify results obtained from computations. The antennas of interest cover the hf range and must be amenable to frequency hopping modulation schemes. Increase in bandwidth of monopole-like structures may be achieved by means of loading/tuning circuits and incremental bandwidth enhancement may be obtained by electronically switching antennna loads and elements. In this project, monopoles with shielded lumped loads are analyzed and results are confirmed experimentally. Also investigated are the coupling of time-domain signals between two closely spaced monopole antennas and the behavior of a time-domain signal injected at one port of a loaded loop antenna above a ground plane and sampled at the other port.

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1. Goal and Summary of Accomplishments

The goal of the research at Clemson University supported by Grant DAAD19-00-1-0401 and reported here has been to better understand the behavior of loaded antennas operating in the time domain (non sinusoidal). The antennas of interest must be ominidirectional, physically robust, of low profile, and suitable for transmission and reception. Although the antennas can be scaled in frequency so that they operate in almost any reasonable frequency range, the most important range of interest is that from approximately 30 MHz to 500 MHz. The ultimate application of the results of this investigation is in the development of ultra broadband antennas for battlefield deployment, with special interest in features associated with structures to be used with frequency hopping spread spectrum modulation schemes. The antenna which is most promising for this application is a modification of the basic monopole antenna. The transient signal on the simple antenna may be due to a transient excitation or it may be caused by a load suddenly switched into or out of an antenna element which otherwise supports time harmonic currents and charges. Significant progress has been made in the development of a method to measure time-domain signals on loaded antennas and on methods to characterize loads on antennas in such a way that the effects of these loads on the antenna current and charge can be accounted for accurately. Not only do the accomplishments in characterizing loads for antennas provide a foundation for controlling antennas currents, hence bandwidth, but also they serve as the basis for determining a Thevenin equivalent circuit of a loaded antenna at the load point. From the time-harmonic equivalent circuit, a time-domain model is to be developed which can be used to analyze antennas subjected to nonlinear loads such as tuning coils with ferrite cores and diodes.

Measurement of Transient Signals on Antennas

We have developed a time marching, numerical solution of the time-domain, integral equation for a thin-wire antenna of arbitrary configuration, which enables us to determine transients on antennas. It can be used to investigate antenna structures which are time dependent, and it can handle non-linear elements such as would be introduced in any model of an electronic switch. There is very little data available which one may use to check the accuracy of numerical results for time-varying antennas. Hence, as part of the research in this program, we have designed an experimental capability for measuring transient signals on wire antennas loaded with linear loads: resistors, capacitors, and inductors. (We do not have the instrumentation needed to measure data for antennas with nonlinear loads like diodes or with time-dependent elements resulting from switching. However, the apparatus that has been designed and fabricated can be used for characterization of nonlinear loads when a sufficiently fast digitizing oscilloscope is available.) Measured and computed data are in very good agreement for monopoles loaded with resistors. Experimental data have been obtained for monopoles loaded with inductors too and for resistor-loaded wire loop antennas.

Analysis of Antennas with Lumped Loads

A second undertaking that has been partially supported under the auspices of Grant DAAD19-00-1-0401 is the development of the capability to reliably incorporate lumped loads (RLC circuits) into wire antenna structures. So that the lumped load obeys the laws of circuit theory, the load must be shielded from the fields created by the current and charge on the antenna element proper. Shields may be used to enhance structural integrity and ensure that the antenna currents couple to the lumped circuits in a way that can be described by network theory. The loads enable one to control the antenna current and thereby control its properties. In addition, the techniques that have been developed to accurately analyze antennas with lumped loads can be extended to provide a basis for determining a time-harmonic Thevinin equivalent circuit at the load port. From this equivalent circuit established over a wide range of frequencies, one can find a time-domain Thevinin equivalent which can be employed to analyze antennas with nonlinear loads such as diodes and inductors with ferrite cores.

An effective way to shield circuit components is to house them inside a tubular element of the antenna, and thereby limit the coupling of the antenna and the circuit element so that it takes place via a gap in the outer surface of the tubular antenna element. Such a configuration lends itself to accurate analysis by a coupling of Maxwell's equations and circuit laws. Coupled integral techniques for analyzing such loaded antenna structures have been developed and reported in the literature, and refinements in this area are continuing. Also, a method for accurately measuring the properties of the loaded antenna has been devised and it is found that computed and measured data are in very close agreement.

2. Papers

Papers based in part on the work supported by Grant DAAD19-00-1-0401 have been submitted to journals, some are already in print, and others are in press. Papers have been presented at conferences too.

(a) Papers published in peer-reviewed journals

F. A. Pisano III, and C. M. Butler, "Analysis of a Cylindrical Antenna Containing an Aperture Coupled Load," **IEEE Trans. Antennas Propagat,** vol. 50, no 4, pp. 457-468, April 2002.

(b) Papers published in conference proceedings

Jeremy P. Rudbeck and Chalmers M. Butler, "Theoretical Analysis and Measurement Strategy of Shielded Loads,"
2002 IEEE AP-S International Symposium, Accepted March 2002.

(c) Papers presented at meetings, abstracts only published in proceedings

F.A. Pisano, III, and C.M. Butler, "Comparison of Load Models for a Thin-Wire Antenna," Digest, 2000 USNC/URSI National Radio Science Meeting, Salt Lake City, UT, p. 352, July 2000.

(d) Manuscripts in press but not yet published

F. A. Pisano III, and C.. M. Butler, "Load Approximations for a Wire Antenna Loaded with a Shielded Network," **IEEE Trans. Antennas Propagat**. , in press.

F. A. Pisano III, C. M. Butler, and J. P. Rudbeck, "Analysis of a tubular monopole loaded with a shielded helical coil," **IEEE Trans. Antennas Propagat**. , in press.

3. Scientific Personnel and Degrees Earned

(a) Faculty

    Chalmers M. Butler, PI (no salary support from grant)

(b) Graduate students and degrees earned

Frank A. Pisano	Ph.D., December 2001
Jeremy P. Rudbeck	in progress